Appendix E
Previous Ecological Investigations

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Table E-1. Previous investigations applicable to WERAs[a] at INEL.[b]

Reference	Applicability: Problem formulation	Applicability: Analysis	Applicability: Risk characterization	Study area	Topic species	Contaminants addressed	Data reported: Habitat	Data reported: Diet	Data reported: Susceptibility to contaminant	Data reported: Biological response	Data reported: Tissue concentration
Anderson 1991	X	X		ICPP	Vegetation Wildlife Soil						
Arthur 1982	X	X	X	RWMC/ SDA	Crested wheatgrass Russian thistle	Pu-238 Pu-239,240 Am-241	Terrestrial				X
Arthur, Connelly, Halford, and Reynolds 1984	X			INEL	Vertebrate survey		X				
Arthur, Markham, Groves, Keller, and Halford 1986	X	X		RWMC/ TSA, SDA	Deer mouse Ord's kangaroo rat		Terrestrial			X	
Arthur, Markham, Groves, and Keller 1987	X	X		RWMC/ SDA	Deer mouse	Radionuclides					
Arthur and Gates 1988		X		INEL	Pronghorn antelope Black-tailed jackrabbit	Trace elements Toxic elements Radiological elements					
Arthur and Janke 1986	X	X	X	RWMC/ SDA	Small mammals Avifauna	Radionuclides	Terrestrial				
Arthur and Markham 1982a	X	X		TRA, RWMC SDA	Coyote	Radionuclides	Terrestrial				
Arthur and Markham 1982b	X	X	X	TRA, RWMC/ SDA	Burrowing mammals Coyote Wheatgrass Russian thistle Soil	Radionuclides	Terrestrial				X(?)
Arthur and Markham	X	X		RWMC/	Soil	Plutonium	Terrestrial				

Table E-1. (continued).

Reference	Applicability: Problem formulation	Applicability: Analysis	Applicability: Risk characterization	Study area	Topic species	Contaminants addressed	Data reported: Habitat	Data reported: Diet	Data reported: Susceptibility to contaminant	Data reported: Biological response	Data reported: Tissue concentration
1983				SDA							
Arthur and Markham 1984	X	X	X	RWMC/ SDA	Soil Crested wheatgrass Deer mouse	Po-210	Terrestrial				X
Blom, Johnson, and Rope 1991		X		TRA	Harvester ant	Cs-137 Co-60	Soil mounds/ terrestrial				
Connelly 1982	X	X	X	INEL	Sage grouse	Radionuclides	Terrestrial/ aquatic	X		X	X(?)
Connelly and Markham 1983	X	X	X	TRA, ICPP, RWMC, CFA	Sage grouse	Radionuclides	Terrestrial/ aquatic			X(?)	X(?)
Craig, Halford, and Markham 1979	X	X	X	TRA, ICPP	Raptor	Radionuclides	Air/ terrestrial				
Craig, Craig, and Powers 1985		X		INEL	Long-eared owl		Air	X			
Evenson 1981		X	X	INEL	Deer mouse	Radionuclides	Terrestrial		X(?)	X	X(?)
Filipovich 1983	X			ARA	Deer mouse Great Basin pocket mouse Least chipmunk Montane vole Ord's kangaroo rat Western harvest mouse Northern grasshopper mouse Sagebrush vole		Terrestrial	X			

Table E-1. (continued).

Reference	Applicability: Problem formulation	Applicability: Analysis	Applicability: Risk characterization	Study area	Topic species	Contaminants addressed	Data reported: Habitat	Data reported: Diet	Data reported: Susceptibility to contaminant	Data reported: Biological response	Data reported: Tissue concentration
Fraley, Bowman, and Markham 1982	X	X	X	ICPP	Rabbit	I-129/I-127	Terrestrial		X (?)	X	X(?)
Groves and Keller 1986	X	X		RWMC/ SDA	Small mammals		Crested wheatgrass Russian thistle Sagebrush				
Halford 1987		X		TRA	Small mammals	Transuranic adionuclides	Terrestrial				X
Halford, Millard, and Markham 1981	X	X		TRA	Duck Geese Swan American coot	Radionuclides	Aquatic				X
Halford, Markham, and Dickson 1982	X	X		TRA	Green-winged teal Mallard Northern pintail Lesser scaup Common goldeneye Bufflehead American coot		Aquatic/air	X		Dose	
Halford, Markham, and White 1983	X	X		TRA	Wing-clipped mallard	Cs-134 I-131 Cs-137 Ba-140 Se-75 Co-58 Zn-66 Co-67 Cr-51	Liquid radioactive waste pond			X	X

Table E-1. (continued).

Reference	Applicability: Problem formulation	Applicability: Analysis	Applicability: Risk characterization	Study area	Topic species	Contaminants addressed	Data reported: Habitat	Data reported: Diet	Data reported: Susceptibility to contaminant	Data reported: Biological response	Data reported: Tissue concentration
Halford and Markham 1978	X	X		TRA	White-footed deer mouse Least chipmunk Ord's kangaroo rat		Terrestrial		X		
Halford and Markham 1984		X		TRA	Mallard	I-129/I-127	Aquatic/air			X(?)	X(?)
Halford and Millard 1978	X			TRA	Vertebrate fauna		Leaching pond (aquatic)				
Howe and Flake 1989	X	X		INEL	Mourning dove		Aquatic/air				
Ibrahim and Culp 1989	X	X		TRA	Net plankton Suspended particulate Sediment	Pu-239 Pu-240 Pu-238	Aquatic				
Janke and Arthur 1985	X	X		RWMC/ SDA, TSA	Cottontail rabbit	Radionuclides	Terrestrial				
Johnson 1979	X			INEL	Rabbits Black-tailed jackrabbit Pronghorn antelope Sheep Cattle		Terrestrial	X			
Johnson and Hansen 1979	X			INEL	Coyote		Terrestrial	X			
Koehler and Anderson 1991	X			RWMC/ SDA	Deer mouse Montane vole Ord's kangaroo rat Townsend's ground squirrel		Terrestrial				

Table E-1. (continued).

Reference	Applicability: Problem formulation	Applicability: Analysis	Applicability: Risk characterization	Study area	Topic species	Contaminants addressed	Data reported: Habitat	Data reported: Diet	Data reported: Susceptibility to contaminant	Data reported: Biological response	Data reported: Tissue concentration
Kuzo, Fraley, Whicker, and Markham 1987	X	X		TRA	Sediment Seston Periphyton	Pu-238 Pu-239,240 Am-241 Cm-242 Cm-244	Aquatic				
Markham 1974	**X**	**X**		**INEL**		**Radionuclides** **Environmental**	**Terrestrial**				
Markham 1979	X	X		RWMC/ SDA	Small mammals Soil	Radionuclides Cs-137 Co-60 Sr-90	Terrestrial				X
Markham, Autenrieth, and Hoskinson 1976	**X**	**X**		**INEL**	**Pronghorn antelope**	**Radionuclides**	**Terrestrial**				X
Markham, Puphal, and Filer 1978	X	X		RWMC/ SDA	Soil Deer mouse	Pu-238 Pu-239 Am-241	Terrestrial				X(?)
Markham, Autenrieth, and Dickson 1979		X		ICPP	Pronghorn	Pu-238 Pu-239,240	Terrestrial/ Air				X
Markham, Halford, and Autenrieth 1980	**X**	**X**		**INEL**	**Pronghorn antelope**	**Sr-90**	**Terrestrial**			X	
Markham, Halford, Bihl, and Autenrieth 1980	**X**	**X**		**INEL**	**Pronghorn antelope**	**I-131**	**Terrestrial**			X	X
Markham, Halford, Autenrieth, and Dickson 1982		X		ICPP	Pronghorn antelope	Radionuclides	Terrestrial				X
Markham, Hakonson, Whicker, and Morton	X			ICPP	Mule deer	I-129	Terrestrial		X (?)	X(?)	X

Table E-1. (continued).

	Applicability						Data reported				
Reference	Problem formulation	Analysis	Risk characterization	Study area	Topic species	Contaminants addressed	Habitat	Diet	Susceptibility to contaminant	Biological response	Tissue concentration
1983											
Markham, Halford, Rope, and Kuzo 1988		X		TRA	Mallard	Plutonium Americium Cesium Strontium	Aquatic/air				
Markham and Halford 1982	X	X	X	TRA, ARA, EBR-II, ICPP, LOFT, NRF, RWMC	Mourning dove	Radionuclides	Terrestrial/ aquatic		X	X	X
Markham and Halford 1985	X	X		ICPP	Pronghorn	Cs-137	Terrestrial/ air				X
Markham and Trost 1986	X	X		INEL	Mourning dove		Terrestrial/ air	X			
McBride, French, Dahl, and Detmer 1978	X	X		INEL	Vegetation						
McGiff 1985	X	X		INEL	Vegetation Pronghorn meat	I-129 I-127	Terrestrial			X	
Millard 1986	X			—	Big sagebrush Wildrye *(E. elymoides)*	Ce-141 Cs-134	Terrestrial				
Millard, Fraley, and Markham 1983	X	X		INEL	Big sagebrush Bottlebrush grass	Ce-141 Cs-134	Terrestrial				
Millard, Whicker, and Markham 1990	X	X	X	TRA	Barn swallow	Radionuclides	Elevated nesting (?)			Growth rate	

Table E-1. (continued).

Reference	Applicability: Problem formulation	Applicability: Analysis	Applicability: Risk characterization	Study area	Topic species	Contaminants addressed	Data reported: Habitat	Data reported: Diet	Data reported: Susceptibility to contaminant	Data reported: Biological response	Data reported: Tissue concentration
Olson and Jeppesen 1993	X	X		INEL	Soils						
Parmenter 1985	X	X		—	Coyote	H-3 Na-22	Terrestrial	X		X	
Petersen and Best 1986	X			INEL	Sage sparrow Brewer's sparrow		Terrestrial/ air	X			
Reynolds 1991	X			—	Harvester ant	—	Soil mounds/ terrestrial				
Reynolds, Connelly, Halford, and Arthur 1986	X			INEL	Vertebrate survey	None	Terrestrial Aquatic				
Kramber et al. 1992	X	X		INEL	Vegetation						
Rope, Arthur, Craig, and Craig 1988	X			INEL, ICPP	Big sagebrush Bluegrass/ muttongrass Bottlebrush grass Soil	Nutrients Trace elements	Terrestrial				X

a. WERAs = Waste Area Group (WAG) environmental risk assessments.

b. Shaded references apply to WAG 9.

Arthur and Gates (1988). Soil ingestion rates were estimated for the pronghorn (*Antilocapra americana*) and black-tailed jackrabbit (*Lepus californicus*). The mean soil intake rates for the pronghorn and jackrabbit were 48.7 and 9.7 grams per day (g/d), respectively. Soil composed 5.4% and 6.3%, respectively, of the pronghorn and jackrabbit total dry matter intake. For both species, the estimated percentage of elemental intake attributable to soil was 75% for Na, Fe, V, and F and 10 to 50% for Mn, Cr, Mg, Ni, K, and Zn. Vegetation consumption resulted in greater than 90% of the daily intake of Ca, Cu, and P.

This article is significant because ingestion of soil is an important exposure pathway for some species of wildlife. The site-specific estimates of soil ingestion could be used as input parameters for exposure assessment. The paper also provides referenced estimates of average daily food ingestion rates for jackrabbits and pronghorn, which could be used for estimating exposure through the food chain for these animals. Data provided for element concentrations in plants (sagebrush and grass) and soil could be used to derive site-specific plant uptake factors for certain elements.

Arthur and Markham (1982). Coyote fecal samples were collected at two sites on the INEL and at an offsite control area. One site was a liquid radioactive waste pond located at the Test Reactor Area (TRA) and the other was a solid radioactive waste pit located at the Radioactive Waste Management Complex/Subsurface Disposal Area (RWMC/SDA). The fecal samples of coyotes at the TRA had elevated concentrations of Cs-137, Sr-90, and Pu-238 versus controls. The increased radionuclide content of the fecal matter was attributed to coyote drinking water from the waste pond or consuming small mammals or both. Elevated Am-241 concentrations in coyote fecal samples collected at the RWMC/SDA were attributed to ingestion of small mammals. Export inventory calculations indicated that Sr-90 and Cs-137 accounted for 86%, 99%, and 99% of the radionuclide inventory estimates within a 6.3-kilometer (-km) radius of each of the SDA, TRA, and control areas, respectively. The results indicate that coyotes can be a transport vector for radionuclides from contaminated sites, but they account for similar or lesser quantities of radionuclide export than other transport sources such as waterfowl and vegetative uptake.

This paper provides important information on transfer of radionuclides through the food chain at the INEL. The data could be used to develop food chain transfer coefficients or estimates of contaminant transport by animal vectors at contaminated sites. The levels of contamination in ecosystem components at the TRA and RWMC have likely changed since this research was conducted, however, as a result of remedial activities and other physical changes at these sites.

Connelly and Markham (1983). Movements and radionuclide concentrations in the muscle and gastrointestinal tract of sage grouse (*Centrocercus urophasianus*) summering near nuclear facilities of the INEL were studied from 1977 to 1980. The majority of grouse were located within 2 km of feeding areas on lawns surrounding the facilities during the summer months but were not near the facilities after September or mid-November. The grouse remained near the facilities for a mean number of 95 days/year (d/y). Mean radionuclide concentrations in muscle (0.29 pCi/g; n = 29) and the gastrointestinal tract (0.80 pCi/g; n = 29) of sage grouse were higher at the TRA and Idaho Chemical Processing Plant (ICPP) than at offsite control areas. Cr-51 had the highest average concentration in the gastrointestinal tract and Cs-137 had the highest average concentration in muscle tissue. Levels of radionuclides in birds at the RWMC were not significantly higher than levels in control birds.

This paper is important for risk assessors because sage grouse are identified as commonly using facility lawns for feeding and loafing and are, therefore, potentially exposed to site contaminants. However, the concentrations of radionuclides in sage grouse were generally lower than those reported for waterfowl and mourning doves in the same areas. This was likely a result of the greater use of TRA ponds by these other birds and the comparatively greater summer home range of sage grouse. Potential exposure of sage grouse and other birds should be evaluated on a site-specific basis during Problem Formulation.

Craig et al. (1979). Concentrations of gamma-emitting radionuclides were determined in young from 17 nests of three species of raptor: American kestrel, long-eared owl, and marsh hawk. The nests were located near the ICPP and TRA. Food habits were determined by examination of castings and prey remains found at the nests. Rodents captured near TRA waste ponds were also analyzed for gamma radiation. Cs-137 had the highest concentration of any radionuclide. Northern harriers measured at 11 and 21 days of age had the most radionuclides detected (nine) at the highest levels (up to 87 pCi/g). The American kestrel also had several radionuclides detected (eight) with activity levels (up to 44 pCi/g) below those found in harriers. Long-eared owls monitored at 15 days of age had very few radionuclides detected (none to one) and had very low levels of activity (up to 0.4 pCi/g). Levels of radionuclides in the raptors' prey were approximately four to 290 times greater than the levels in the raptors at TRA. Doses to raptors from internal gamma radiation were estimated to range from 0 to 0.1 millirems per day (mrem/d). Based on these results, the authors suggest that raptors were exposed to radionuclides through their prey. Concentrations in raptors were diluted relative to their prey, most likely as a result of consumption of uncontaminated prey.

This article is significant for risk assessors in that it provides data on radionuclide exposure for raptors at the INEL and transfer through the terrestrial food chain.

Halford and Markham (1978). Small mammals were live trapped in a dry liquid radioactive waste pond at the TRA and had thermoluminescent dosimeters (TLDs) implanted. Upon recapture, the TLDs were removed and dose rates were determined. Deer mice (*Peromyscus maniculatus*) were the most numerous species trapped. All species captured on the site received significantly greater doses than controls. The mean deer mouse dose equivalent rate was 160 mrem/day (with a range of 7 to 982 mrem/day), which was 356 times the dose rate received by control deer mice. These dose rates would result in a 1-year lifetime average exposure of 58 rem with a maximum exposure of 358 rem. Deer mice also had the highest radionuclide concentrations in whole body tissues. The contribution of internal radionuclides to the measured dose was stated as negligible; however, as whole-body radionuclide counts increased, so did internal dose rates. This indicates that the internal dose rate may become significant for the more highly exposed individuals (>100 pCi/g whole-body inventory).

Because this paper presents measured radiation dose rates to small mammals at the INEL, it can be used as a "reality check" by risk assessors attempting to estimate small mammal exposure to radionuclides. The paper presents the total whole-body radiation dose (as measured by surgically implanted dosimeters) and the internal, whole-body radiation dose (calculated from measured radionuclide activities in the body). The total whole-body dose was considerably greater than the internal whole-body dose and, thus, suggests that deer mice, kangaroo rats, and chipmunks at the INEL receive a greater radiation dose from the surrounding environment than from consumption of contaminated food. This observation should be considered by risk assessors when estimating radiation doses to small mammals at the INEL. A similar study on radiation dose rates received by small mammals at the INEL is described by Arthur et al. (1986).

Halford and Markham (1984). Wild free-ranging waterfowl were collected from the liquid radioactive waste pond at the TRA and on control areas to determine the ratios of I-129 to I-127 in muscle tissue. Wing-clipped mallards were also released on test and control areas for from 2 to 156 days before collection and testing. The mean iodine ratios for wild waterfowl were not significantly different between test and control areas. However, the wing-clipped waterfowl iodine ratios from the waste pond were significantly higher than all the other tested birds. Although there was no significant correlation between time spent on the waste pond and iodine ratios, the authors felt it was the most likely reason for the higher iodine ratios in wing-clipped mallards. The total whole-body dose from I-129 ranged from 1.0×10^{-5} mrad for control waterfowl to 3.0×10^{-5} mrad for waste pond waterfowl.

Halford et al. (1981). Wild waterfowl were collected from a liquid radioactive waste pond at the INEL and analyzed for radionuclide content. Up to 29 radionuclides were found in body tissues of the waterfowl. Eighty percent of the total radioactivity in the collected waterfowl tissues was from radionuclides with half-lives of less than 1 year. Those radionuclides with half-lives of less than 15 hours were not detected because of their radioactive decay before analysis. The highest sum of all radionuclide concentrations occurred in the gastrointestinal tract, followed by feathers, liver, muscle, and skin. Certain radionuclides concentrated to a greater extent in some of the tissues versus others and the total average radionuclide concentration in wild waterfowl was 27,798 pCi/g fresh weight. Co-60 and Cs-137 were the only two radionuclides detected in control waterfowl tissues at levels below 1 pCi/g.

The data in this paper on the activities of 29 gamma-emitting radionuclides in waterfowl have three potential uses for ecological risk assessors: (1) to calculate site-specific bioaccumulation factors (BAFs) for waterfowl at the INEL Site (assuming sediment and water activities of the nuclides have been measured); (2) as a "reality check" by risk assessors modeling the transfer of radionuclides to waterfowl at the site; and (3) to calculate internal radiation dose rates. In addition, the paper may be of use to human-health risk assessors because it estimates the radiation dose to a human from consumption of contaminated waterfowl.

Halford et al. (1982a). Cs-137 and Cs-134 were the two radionuclides most responsible for internal and external doses to wild free-ranging waterfowl from a liquid radioactive waste pond at the INEL. Other contributors included Cr-51, Co-58, Co-60, Zn-60, Se-75, and I-131. The lowest and highest average internal doses for individual species were 330 mrad (range 1 to 1,300 mrad, $\underline{n} = 6$) for the lesser scaup (*Aythya affinis*) and 2,000 mrad (range 40 to 4,000, $\underline{n} = 2$) for the American coot (*Fulica americana*), respectively. An average internal dose for all wild waterfowl (700 mrad) was added to the ventral and dorsal external dose to get the average total dose rate (1,900 mrad) for a wild waterfowl residing at the ponds for 6 days. Because of modeling factors and other assumptions, these estimates likely overestimate the actual exposure, possibly by a factor of five or more. Wing-clipped mallards held on the ponds for 43 to 145 days also had the internal, external, and total doses calculated. Waterfowl residing on the ponds for 145 days were exposed to an average total dose of 32,145 mrad.

Because this publication presents measured radiation dose rates to waterfowl and radionuclide activity in waterfowl muscle, it can be used as a "reality check" for risk assessors attempting to model waterfowl exposure to radionuclides at the INEL site. It is interesting to note that waterfowl contained higher radionuclide concentrations and received higher doses from internal radionuclides than other birds and small mammals studied near the liquid radioactive waste disposal area (compare with Halford and Markham 1978).

Halford et al. (1982b). The biological elimination of nine gamma-emitting radioisotopes was studied in wing-clipped mallards held on a liquid radioactive waste pond at the INEL. Whole-body and feces-urine radioactivity counts were made for 51 days after the ducks were removed from the pond, then they were dissected and tissue analyzed. Body burdens of nine radionuclides were at an average of 90% of equilibrium with the radioactive waste pond water after 68 days on the pond. The biological half-lives in the mallards were 10 days (Cs-134), 10 days (I-131), 11 days (Cs-137), 22 days (Ba-140), 26 days (Se-75), 32 days (Co-58), 67 days (Zn-66), 67 days (Co-67), and 86 days (Cr-51). The gastrointestinal tract had the highest concentrations of radionuclides immediately after removal from the ponds, followed by the feathers, liver, and muscle. After 51 days, the feathers had the highest concentrations followed by the liver, muscle, and gut.

Ibrahim and Culp (1989). Concentrations of Pu-239, Pu-240, and Pu-238 were determined in water, net plankton, suspended particulate, and sediment at TRA waste ponds. The oxidation states of plutonium were also measured and found to be mostly Pu^{+3} and Pu^{+4}, unlike with larger natural water bodies, which usually support plutonium in the +5 and +6 oxidation states. The highest plutonium concentrations were found in net plankton, but sediments were found to be the main reservoir for plutonium in the pond. The lowest plutonium concentrations were in filtered water. This indicates that the plutonium is taken up by or bound to the plankton in the water column before eventually settling to the bottom sediments where it remains.

Kuzo et al. (1984). The distribution and kinetics of Pu-238, Pu-239/240, Am-241, Cm-242, and Cm-244 were studied in abiotic and biotic components of test reactor leaching ponds located on the INEL from June to July 1979. The highest transuranium concentrations were recorded for seston and periphyton with the lowest concentrations for filtered water. Concentration ratios for each nuclide differed among components with the highest values recorded for seston and periphyton matrices (10^4 to 10^5) and lowest values for sediments (10^2 to 10^3). Concentration ratios were similar for all plankton types (10^4). For each component, plutonium isotope concentration ratios were consistently higher than values for americium and curium nuclides. Intra-element differences were observed for concentration ratios between the isotopes of plutonium (Pu-239/240 > Pu-238) and also the isotopes of curium (Cm-244 > Cm-242). An in situ experiment monitoring sorption of the five transuranium isotopes by soil resulted in continued nuclide accumulation throughout a 15-day experiment with the overall soil nuclide concentrations positively correlated with nuclide concentrations in filtered water or seston or both. Model parameter estimates describing the fractional rates of increase were similar among Pu-238, Am-241, Cm-242, and Cm-244 ranging from 4.4 to 0.59 ´ 10^{-3}/hour to 6.0 ´ 10^{-3}/hour. In contrast, this value for Cs-239/240, 1.3 ´ 10^{-3}, was lower than for the other nuclides. Possible explanations for the observed similarities and differences in the distribution and kinetics of the five transuranium nuclides are discussed.

Markham (1974). Routine environmental monitoring results are presented for the air, soil, surface water, and groundwater of the INEL in 1973. The data from on-site and nearby community sampling locations were compared to background concentrations and the applicable standards established by the U.S. Atomic Energy Commission. Some concentrations of radionuclides in air, soil, and surface water were above background concentrations but are infrequent and generally near known source areas for radionuclides.

Markham and Halford (1982). Cs-137 occurred frequently in mourning dove (*Zenaida macroura*) tissues from several areas on the INEL. The highest average concentrations in dove muscle tissue were found at the TRA and ICPP at 15.85 pCi/g (1976) and at 3.24 pCi/g (1974), respectively. Average radionuclide concentrations in the gastrointestinal tract of the doves were found to be highest (41.1 pCi/g) at the TRA. Twenty other radionuclides were detected in dove tissues and, of these, Cs-134, I-131, Co-60, and Cr-51 were the most significant contributors to the total radiation dose for the dove.

This paper is of interest to risk assessors in that it documents mourning dove exposure to radionuclides at seven INEL facilities [TRA, ICPP, RWMC, Test Area North (TAN), Experimental Breeder Reactor II (EBR-II), Auxiliary Reactor Area (ARA), and Naval Reactor Facility (NRF)] as well as several other locations. According to the authors, the radiation dose rates received by doves are similar to or less than the doses received by raptors, deer mice, or barn swallows studied at the TRA and ICPP. The exposure routes for doves at various sites are discussed, including drinking and feeding. The levels of radionuclides reported for doves could be used to estimate the potential exposure to dove predators such as raptors.

Markham and Halford (1985). During 1975, additional prefilters and high-efficiency particulate air (HEPA) filters were added to the existing air filtering system for atmospheric effluents from the ICPP at the INEL. Prior to filter installation, the average Cs-137 concentrations in pronghorn muscle and liver samples collected near the ICPP were 13 (0.57 pCi/g) and 18 (1.04 pCi/g) times, respectively, higher than those concentrations found in the same tissues of control animals (0.04 and 0.06 pCi/g for muscle and liver, respectively). Muscle and liver samples collected after filter installation (0.05 and 0.07 pCi/g for muscle and liver, respectively) had only 2.5 times the Cs-137 concentrations found in control samples (0.02 and 0.03 pCi/g in muscle and liver, respectively).

Markham et al. (1980a). Metacarpal bones were collected from pronghorn antelope (*Antilocapra americana*) near the ICPP and adjacent areas in the INEL in southeastern Idaho. Control bones were collected from offsite animals at high elevations. Average concentrations in metacarpals were 9.6 pCi/g (ash) within 10 km of the ICPP, 4.0 pCi/g for animals on the remainder of the INEL, and 5.5 pCi/g for control animals. The ICPP atmospheric releases of Sr-90 appeared to have caused a significant ($P < 0.05$) increase in Sr-90 concentrations in pronghorn bones with 10 km of the ICPP as compared to bones of other INEL pronghorn. However, the ICPP pronghorn bone Sr-90 concentrations were not statistically different from that occurring in bones of the control animals from higher elevations. Antelope near the ICPP received approximately double the radiation doses to bone compared to the dose received by other ICPP sources that resulted in an estimated average radiation dose of 40 mrad/year to endosteal cells and 20 mrad/year to active bone marrow.

Markham et al. (1980b). I-131 concentrations were determined in air, milk, and pronghorn (*Antilocapra american*) thyroids from southeastern Idaho during each year from 1972 to 1977. Samples were collected in the vicinity of the INEL, which has 17 operating nuclear reactors, a fuel processing plant, and a nuclear waste management facility. Samples were also collected from control areas. During the study, fallout occurred from five Peoples Republic of China aboveground nuclear weapon detonations. All I-131 detected in air and milk samples was attributed to fallout from the Chinese nuclear tests. I-131 occurred in antelope thyroids during the five fallout periods and following at least one atmospheric release from facilities at the INEL. Thyroids were the most sensitive indicators of I-131 in the environment followed by milk and then air. Maximum concentrations in thyroids, milk, and air were 400, 20, and four times higher, respectively, than their respective detection limits.

Markham et al. (1988). Concentrations of Sr-90, Pu-238, Pu-239/240, Am-241, Cm-242, and Cm-244 were determined in tissues of mallard ducks (*Anas platyrhynochos*) maintained for 43 to 145 days on radioactive leaching ponds at the TRA. The highest concentrations of transuranics occurred in the gastrointestinal tract, followed closely by feathers. Approximately 75%, 18%, 6%, and 1% of the total transuranic activity in tissues analyzed were associated with the bone, feathers, gastrointestinal tract, and liver, respectively. Concentrations in gastrointestinal tracts were similar to concentrations in vegetation and insects in the littoral area of the ponds. The calculated total dose rate to the ducks from both Sr-90 and the transuranic nuclides was 0.69 mGy/d, of which 99% was to the bone. Based upon average concentrations in experimental ducks and on surveys of wild waterfowl using this area, a conservative estimate of transuranic activity exported by wild ducks using the ponds during 1 year was 305 nCi. Similarly, the total amount of Sr-90 exported in muscle, bone, and lung of wild ducks in 1 year was 68.70 μCi.

Millard et al. (1983). Deposition velocities and retention times were obtained for submicron aerosols of Ce-141 and Cs-134 deposited in two cool desert plant species, big sagebrush (*Artemisia tridentata*) and bottlebrush grass (*Sitanion hystix*). Mean deposition velocities for sagebrush were 0.18 cm/second (Ce-141) and 0.13 cm/second (Cs-134). Species differences were significant; however, nuclide differences were not significant. The loss of activity on the vegetation consisted of two components. A rapid initial loss was found with effective half-times of approximately 1 day (1 to 8 days for Ce-141 and 0.6 day for Cs-134) on sagebrush and approximately 2 days (2.8 days for Ce-141 and 2.3 days for Cs-134) on grass. This was followed by a slower, long-term loss with effective half-times ranging from 11 days for Ce-141 and 15 days for Cs-134 on sagebrush to 9 days for Ce-141 and 11 days for Cs-134 on grass.

Millard et al. (1990). Concentrations of radionuclides and the potential effects on barn swallows were examined at the TRA waste ponds. The swallows were found to feed on pond arthropods and use contaminated mud for nest building. More than 20 radionuclides were detected in immature and adult birds. Cr-51 was found in the highest concentrations and 72% of the total dose resulted from Na-24. The total mortality rate of the swallows was not found to be different from control populations, but the first clutch of young swallows was found to have lower growth rates and lower body weights than controls. These depressed growth factors were not found to be below the normal range of values, however, and could not be attributed to exposure to radioactivity.

Reynolds et al. (1986). The relative abundance, habitat use, and seasonal occurrence are reported for the six fish, one amphibian, nine reptile, 164 bird, and 39 mammal species recorded at the National Environmental Research Park in southeastern Idaho.

Blom et al. (1991a). Nest densities of harvester ants (*Pogonomyrmex salinus* Olsen) varied from 0 to 164/hectare (ha) for different vegetation communities on the INEL. The highest mean nest density was found on plots within juniper communities, but the greatest density for a single area was found in sagebrush (*Artemisia tridentata wyomingensis*) communities. The authors hypothesize that soil characteristics may play a more important role than vegetation type in the determination of nest densities. This document cites other investigations that indicate that harvester ants may burrow to depths of 2.7 m below the ground surface.

Harvester ants may be important components of the ecosystem at some INEL hazardous waste sites (see also Blom et al., 1991b) and may need to be considered as a contaminant transport mechanism or measurement species in the problem formulation phase. The information in this paper may also help in the calculations of exposure during the analysis phase.

Blom et al. (1991b). Geometric mean concentrations of Cs-137 (10 Bq/g) and Co-60 (1.8 Bq/g) in harvester ant mounds near (0 to 6 m) the TRA liquid radioactive waste pond were higher than in soils surrounding the mounds or in offsite mounds. Mounds are created from vertical exhumation of soils by the ants as they build nests in the subsurface soil. The subsurface soil became contaminated with radionuclides because of the movement of radioactive waste from the ponds through adjacent soils. Erosion of contaminants from the mound to surrounding areas was not apparent. However, the authors suggest that radionuclide transport from the mounds cannot be ruled out because colonies can persist up to 50 years and may undergo erosion by wind and rain during this period. Redistribution of radionuclides could also occur as a result of vertebrates digging in the mounds or because of harvester ant colony relocation.

These processes may be considered by risk assessors during problem formulation at INEL hazardous waste sites where ant density is high. The concentrations of radionuclides detected during this investigation may also be useful in the exposure assessment of the analysis phase of ecological risk assessment (ERA).

Craig et al. (1985). Mammals made up 93.5% of the diet of long-eared owls at the INEL. The authors identify the mammalian species and calculate the percent biomass each species contributed toward the owls' diet.

The percent biomass contributed to the owls' diet by each species provides documented evidence for the development of an exposure model for the owl. This would be most helpful in the analysis phase of the risk assessment.

Halford (1987). Twenty-four (eight adult and 16 juvenile) pen-reared mallards (*Anas platyrhyncos*) were wing-clipped and released onto a liquid radioactive waste pond at the INEL for 56 to 188 days. Nine radionuclides were detected consistently in the mallard's tissues after residing on the ponds. These were Co-60, Cr-61, Zn-65, Se-75, Ag-110, I-131, Cs-134, Cs-137, and Hg-203. No adult or juvenile or time-related factors are provided nor are any concentrations given in the publication.

The identification of nine radionuclides in the tissues of the mallards may help select the most appropriate contaminants of potential concern (COPCs). The COPCs selection occurs in the problem formulation phase of ERA.

Halford and Millard (1978). An inventory of the terrestrial vertebrate fauna and the seasonal occurrence of each species was determined for the radioactive waste pond at the TRA. The pond was found to be a food, water, and habitat source for many species. Three reptile, 11 mammal, and 94 bird species were identified over a 4-year period. The bull snake was the only common reptile seen at the pond. The most abundant small mammal was the deer mouse. Mule deer were observed drinking from the pond on several occasions. Four raptor species were seen at the pond. Northern harriers nested near the site each year of the study and were common. Kestrels were the only other common raptor seen at the pond. Game birds frequenting the ponds included mourning doves, sage grouse, and waterfowl. Other birds commonly using the pond area were killdeer, spotted sandpipers, and barn swallows.

The identification of species inhabiting TRA waste ponds may be very useful in determining the ecosystems components and the ecological endpoints during problem formulation. The presence of these species at TRA waste ponds also provides insight into the species likely to be found at other WAGs with ponds.

Howe and Flake (1989a). Mourning doves from the INEL use the manmade ponds for watering, feeding, gritting, loafing, and courting. The use of the ponds by the doves peaked in the morning (from 0800 until 1300 hours) and evening within 30 minutes before and after sunset. Monthly pond use did not vary greatly during the summer months and the average number of mourning doves arriving daily at a pond varied from none to 80 birds and from 0.5 to 32.3 birds when averaged over individual months.

This definition of use of manmade sands by doves at the INEL may be helpful while writing the problem formulation phase for areas with ponds. Exposure models for the dove may also be refined using these data. This data use supports the analysis phase.

Howe and Flake (1989b). Ground nesting mourning doves were studied on the INEL from 1983 to 1985. Nests located on the ground were difficult to locate; density on the INEL was 0.02 nests/ha. Of a total of 24 active nests, young doves fledged from 75% of the active nests, and 63% of the total number of nests found, over the 3-year study. Survival of the doves from beginning of incubation to fledgling was 0.50. Peak hatching occurred the fourth week of June, the third week of July, and the first two weeks of August. It appears that the doves prefer to nest on the ground under big sagebrush with a good deal of nearby grass cover, surrounding the nest.

Similar to the other Howe and Hake (1988, 1989a) investigations, this article supports the problem formulation and analysis phases of ERA. This article also presents nesting success data that may be useful in risk characterization.

Markham and Trost (1986). Mourning doves of the INEL commonly ate only 11 species of plants. Of these Halogeton (*Halogeton glomeratus*) and Indian ricegrass (*Oryzopsis hymenoides*) made up 48% of the doves' diet. The remaining plant species included wheat (*Triticum aestivum*), barley (*Hordium vulgare*), oats (*Avena sativa*), pigweed (*Amaranthus glomeratus*), common vetch (*Vicia* spp.), collomia (*collomia* spp.), barnyard grass (*Echinochloa crusgalli*), Gromwell (*Lithospermum rudrale*), and cottonwood (*Populus* spp.). The presence of cereal grains indicated that the doves were leaving the INEL for some of their food requirements. Grit was present in 63% of the crops and provided an average of 14% of the mass of the contents.

The study of doves may aid in the selection of measurement endpoints and exposure pathways within the problem formulation. The specific data on the percentage of diet made up by different vegetation and grit may be useful in the exposure assessment during the analysis phase.

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